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The Joint Virtual Laboratory (JVL) automation and communications system integrates live, virtual, and constructive interactive simulations consistent with the TRADOC Analysis Center (TRAC) mission to support Joint, DA, and TRADOC clients. The JVL provides an environment that facilitates insertion of emerging models, simulations, and software developments into the planning and execution of Advanced Warfighting Experiments (AWE). Development and installation of the Eagle Corps Level Computer Generated Forces (CLCGF) model in the JVL is a centerpiece of the DIS Master Plan.

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EXECUTIVE SUMMARY

The Joint Virtual Laboratory (JVL) automation and communications system integrates live, virtual, and constructive interactive simulations consistent with the TRADOC Analysis Center (TRAC) mission to support Joint, DA, and TRADOC clients. The JVL provides an environment that facilitates insertion of emerging models, simulations, and software developments into the planning and execution of Advanced Warfighting Experiments (AWE) – namely Advanced Warfighting Demonstrations (AWDs) and Advanced Technology Demonstrations (ATDs). Development and installation of the Eagle Corps Level Computer Generated Forces (CLCGF) model in the JVL is a centerpiece of the DIS Master Plan.

JVL allows the potential of Distributed Interactive Simulations to approach reality in three major areas: (1) embedding warfighter and soldiers in-the-loop throughout Concept Development and Research, Development and Acquisition (RDA), (2) allowing commanders, staff, and soldiers to train exactly as they intend to fight, and (3) fighting the plan first. Additionally, JVL provides an environment through which the command and control process can be structured by inserting "live" command staffs into a "virtual" battle. TRAC, as an Army domain leader, will use JVL to investigate Advanced Concepts and Requirements (ACRs). TRAC will also use JVL to support Test and Evaluation of Military Operations (TEMO) and RDA activities.

TRAC required the ADST Contractor to provide the design, engineering, testing, installation, and integration of (1) a computer and communication network system and the (2) delivery, integration, and testing of the JPSD ADS software into the standing JVL software environment. The acceptance testing verified that the JVL can successfully run sustained and simultaneous interactive simulations and applications software internal to JVL. Due to TRAC security issues, the JVL network runs only in an unclassified mode. The computer communications network provided, however, will support both classified and unclassified network activity at the same time. This use is at the discretion of the TRAC JVL Facility Operations Manager.

The work was accomplished over the time period of 27 September 1996 through 31 January 1998. The lengthy time frame was due to the spotty availability of the JVL because of TRAC's use of the facility. The subcontractor team adjusted dynamically the delivery, installation, integration, and testing of the computer and communications network and the JPSD ADS software tools. The subcontractor team easily accommodated these adjustments.

1. Background

1.1 Introduction

The purpose of this final report is to document the subcontractor effort that supported the JVL integration contract, performed as DO #0028 under the Lockheed Martin Corporation (LMC) ADST II contract with STRICOM. This report includes a description of the overall effort and the final testing.

1.2 Project Overview

The Joint Virtual Experimentation Laboratory (JVL) project was based on the requirements established by the Army DIS Program and in the DIS Master Plan. The Master Plan defines DIS as:

"A synthetic environment within which humans may interact through simulation(s) and/or simulators at multiple networked sites using compliant architecture, modeling, protocols, standards and databases."

JVL is now a fully operational computer and communications system capable of simultaneously supporting distributed interactive simulation and warfighter/technology demonstrations. The JVL is being provided for the TRADOC Analysis Command (TRAC), at Funston Hall, FT. Leavenworth, KS.

JVL allows the potential of Distributed Interactive Simulations to approach reality in three major areas: (1) embedding warfighter and soldiers in-the-loop throughout Concept Development and Research, Development and Acquisition (RDA), (2) allowing commanders, staff, and soldiers to train exactly as they intend to fight, and (3) fighting the plan first. Additionally, JVL provides an environment through which the command and control process can be structured by inserting "live" command staffs into a "virtual" battle. TRAC, as an Army domain leader, will use JVL to investigate Advanced Concepts and Requirements (ACRs). TRAC will also use JVL to support Test and Evaluation of Military Operations (TEMO) and RDA activities.

1.3 JVL Uses

The objective of the JVL effort is to provide an environment for dedicated research and development of the analytic and software infrastructures needed to support analysis of broad Joint and Army issues and designated studies such as Information Operations and key Force XXI campaign issues. The JVL facility will be used to:

- Generate synthetic battles from Corps to individual vehicles through the use of distributed interactive simulations,

- Complement and enhance ongoing efforts of TRAC, the MITRE Corporation, the TRADOC family of Battle Command Laboratories, the National Simulation Center, the Joint Precision Strike Demonstration, and other geographically separated networked activities, and
- Support diversified Joint, Department of the Army, and TRADOC clients who require warfighting simulation and analyses.

1.4 Technical Overview

The technical approach to the JVL involved a 2 phase effort of integrating a (1) LAN/WAN design based upon Asynchronous Transfer Mode (ATM) technology and (2) JPSD Advanced Distributed Simulation (ADS) tools. The major issue for the effort was the fact that the JVL was in use most of the time over the period of performance. It was necessary to dynamically adjust integration schedules for both phases to meet TRAC needs of the facility. For Phase I, ATM Network switches, platform cards, and Fiberoptic cabling were purchased and installed into the JVL. The network was activated, configured and tested standalone and with the JVL operational loading. For Phase II, the JPSD ADS tools consisting of the Data gateway (DGW), Tactical gateway (TGW), Packet Forwarder, Listen_PDUs, and Reinit, were delivered and integrated on the JVL platforms. They were activated, configured, and run with the standing JVL DIS and C4I systems.

1.5 Achievement Summary:

- Phase I completed with the delivery, integration and testing of the ATM LAN/WAN.
- Phase II completed with the delivery, integration and testing of the JPSD ADS technologies into the TRAC DIS environment.

2. Applicable Documents

2.1 Government

-ADST II Work Statement for the Joint Virtual Laboratory (JVL), May 14, 1997, AMSTI-96-W045, Version 2.6

2.2 Non-Government

None

3. System Description

3.1 System Configuration and Layout

The Joint Virtual Lab (JVL) of the Training and Doctrine Command (TRADOC) Analysis Command (TRAC), at Funston Hall, FT. Leavenworth, KS, contains a variety of analysis models simulations, networks, Semi-Automated Forces (SAF) capabilities, displays for monitoring the battlefield, utilities to facilitate exercises, automated data collection capabilities, and data reduction and analysis subsystems.

The final test was conducted using assets interconnected on the Ethernet LAN, and ATM via thin net and Fiberoptic cabling. Simulation assets used the Distributed Interactive Simulation (DIS) 2.04 protocol. Table 1 lists assets used at the JVL.

JVL ASSET	PURPOSE	PROTOCOL
Eagle	Aggregate Force on Force, Theater level Scenario driver and CLCGF tool	DIS
Stealth	3D Battlefield Display for JVL	DIS
ModSAF Workstations	Semi-Automated Forces for Blue and Red test scenario units, CLCGF SIU, JSTARS	DIS
ModSAF SIU	CLCGF Simulation Interface Unit	DIS
ModSAF Plan View Display	Terrain Map of the battlefield for Exercise Control	DIS
ModSAF Data Loggers	Record of DIS PDUs for Data Collection & Analysis	DIS

Table 1. ADST II JVL Assets

In addition to the assets listed in Table 1 above, the JPSD tools were incorporated on five Sun workstations, and tested with the MCS/P C4I system required to support the experiment. Figure 1 depicts the Hardware and Software tools used to support the experiment.

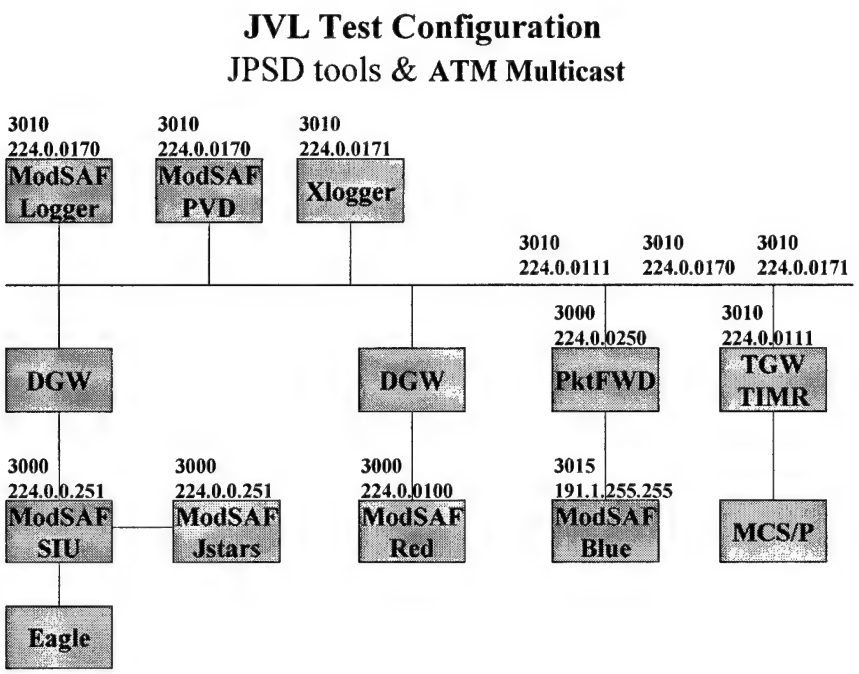

Figure 1. JVL Hardware and Software tools Diagram

3.2 Description of Software Tools

The following JPSD ADS tools were used:

- **Data Gateway (DGW).** The Data Gateway software was developed by SAIC of Arlington, VA for the JPSD Program. It is designed to reside on multi-processor Sun workstations and provides Dynamic Interest Management of DIS PDUs over ATM virtual networks.

- **Tactical Data Gateway (TGW).** The Tactical Data Gateway software was developed by SAIC of Arlington, VA for the JPSD Program. It is designed to reside on multi-processor Sun workstations and provides Dynamic Interest Management of DIS PDUs to and from the Tactical Interest Manager Reflector (TIMR) over ATM virtual networks and the Tactical networks.

- **Tactical Interest Manager Reflector (TIMR).** The Tactical Interest Manager Reflector software was developed by SAIC of Arlington, VA for the JPSD Program. It is designed to reside on Tactical C4I workstations and provides the interface between the Tactical Systems and the TGW over ATM virtual networks and the Tactical networks.

- **Packet Forwarder.** The Packet Forwarder software was developed by SAIC of Arlington, VA for the JPSD Program. It forwards UDP and TCPIP traffic, bearing the Simulation and tactical messaging data, between standard ethernet networks and ATM virtual networks.

- **Listen_PDUs.** The Listen_PDUs software was developed by SAIC of Arlington, VA for the JPSD Program. The application monitors the ethernet and ATM virtual network traffic.
- **Reinit.** The Reinit software was developed by SAIC of Arlington, VA for the JPSD Program. The application is used to dynamically initialize and re-initialize the Interest of the DGWs and TGWs.
- **ModSAF.** ModSAF was used for the JVL testing. ModSAF was used for Red and Blue units and entities. ModSAF provided the two Armor Companies, plus the Company Commanders for a move to contact scenario as generated in Eagle as Aggregate. The ModSAF SIU (CLCGF) was used to provide the deaggregation of the aggregate units generated in Eagle. The ModSAF logger was used for recording and play back of the scenario to insure the interest management runtime architecture was reconfigurable within the JVL ATM LAN and ethernet LAN.
- **Eagle.** The Eagle Analysis model is the aggregate force on force model that is the keystone to the CLCGF tool. The JVL test scenario was executed using the CLCGF tool.
- **Xlogger.** Xlogger is a generic 3rd party tools brought in to test non-programmatic tools to show how to use the JPSD ADS tools.
- **JVL ATM LAN Configuration.** A JVL ATM LAN configuration was used with fiberoptic cable infrastructure.

4. Conducting the Final Test

4.1 JPSD Tools testing

The DGW w/IR was tested using multicasting addressing and assigned PDUs interest requests. Two workstations were used as DGW w/IR to pass PDUs from two ModSAF workstations. The ModSAF applications were generating DIS entities. Each application received the PDUs of the others respective entities via the DGW Interest Management. Different multicast addresses were assigned to the two DGWs. The test was successful in passing the PDUs between the two ModSAF workstations via the JPSD DGWs.

The TGW and TIMR were tested by passing Moving Target Indicator (MTI) signal PDUs from the JSTARS ModSAF to the reconfigurable workstation (RCW). A multicast address was assigned to the TGW that would allow it to receive the signal PDUs from the JSTARS. The TGW received the signal PDUs and converted them into tactical messages. The TIMR was tasked to pass MTI messages from the TGW to the RCW. The test was successful.

The Packet Forwarder was tested by passing PDUs between the ethernet and ATM. One ModSAF was set to pass PDUs using the broadcast ethernet and another was set to pass PDUs using ATM multicasting. Within the Packet Forwarder, the ethernet side was set to

broadcast and the ATM side set to the same multicast address as the ModSAF. All of the PDUs that were produced by the two ModSAFs were past between each other. The test was successful.

The ModSAF Logger and the Xlogger were tested on the ethernet and ATM LAN. While passing PDUs on the ethernet and ATM, the loggers were set to broadcast on the respective nets and logged the PDUs. The loggers were then set to a specific multicast address and port, the same as the ModSAF, and played the recorded PDUs back. The test was successful.

4.2 JVL Standing Architecture Test

One criteria of success for the integration of the ATM LAN and JPSD ADS tools was the non-interference of both to the standing JVL tool use, and tool configuration. This was demonstrated by allowing the JVL staff to execute the use of their tools while the JPSD tools were in use and all the JVL computers running on the ATM LAN. The JVL staff was able to use their tools on the ATM LAN with the JPSD tools running in real time. The standing JVL tools included the Eagle Analysis Model, MCS/P, standard ModSAF, TRAC CLCGF Eagle, TRAC CLCGF ModSAF, and standard ModSAF Logger.

4.3 JVL Communications Concept of Operations

The JVL is now a fully operational automation and communications system capable of simultaneously supporting interactive simulations, warfighting and technology demonstrations. To accomplish this the JVL uses primarily makes of Sun SparcStations and Silicon Graphics (SGI) workstations. The JVL Local Area Network (LAN) is capable of operating in classified and unclassified mode or both simultaneously. When operating in both unclassified and classified modes simultaneously the LANs are physically separated by using the patch panels. Figure 2 shows the JVL Network Connectivity Layout.

JVEL NETWORK CONNECTIVITY LAYOUT

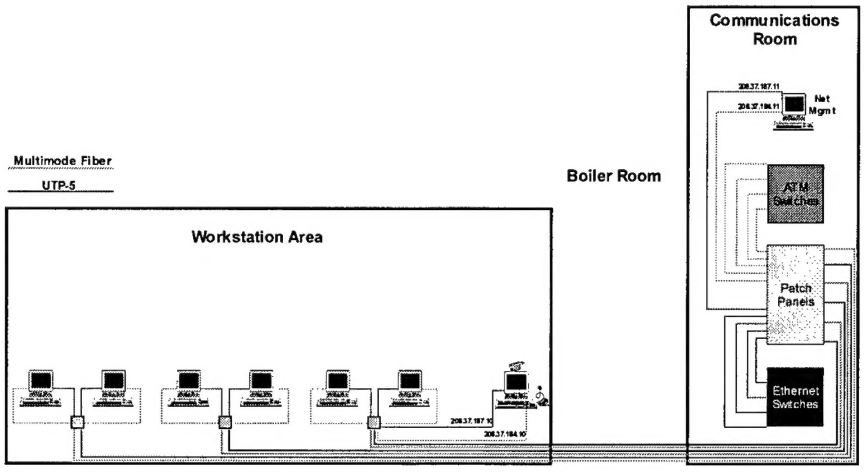

Figure 2. JVL Network Connectivy Layout

5. The JVL ATM LAN

5.1 Traffic Analysis

The primary JVL LAN is now Asynchronous Transfer Mode (ATM). The ATM LAN provides a dedicated OC-3 (155 Mbit) link to each workstation. Redundancy for the system is provided by an additional 10BaseT switched Ethernet LAN providing a 10 Mbit dedicated link to each workstation.

The same type of workstations used on the JVL LAN have been tested for data throughput at the Integration and Evaluation Center (IEC) at FT Belvior, VA. The tests were conducted using a utility named NNTCP. NNTCP generates TCP traffic and passes the traffic from the workstation to the network at the highest capacity of the workstation. The tests showed that a Sun SparcStation can transfer data on the ATM network at a rate of 70 Mbits per second from disk and 100 Mbits per second from RAM. The SGI results were similar except the data transfer from memory was better at 110 Mbits per second. The LAN latency during the tests was between zero and 3 milliseconds, well within the performance specifications needed for the simulation models.

The test at the IEC shows that the ATM LAN has more than enough capacity to handle the data that is transferred by the workstations. The ATM LAN will scale as the JVL increases in size simply by nature of switching. Switching provides each workstation a dedicated OC-3 link therefore overall performance of the LAN is not affected as workstations are added.

5.2 Physical Infrastructure

There are approximately 32 conduits run from the workstation area to the communications room. Each conduit contain at least two pair of MM fiber-optic and two UTP-5 cables. In the workstation area, the MM fiber-optic and the UTP-5 cables terminate in a small junction box. Patch cables are used to connect the workstations to the junction box. SAIC furnished three communications racks. The communications racks are shown in Figure 3. One rack is used for the three ATM switches, one rack for the Ethernet switches, and the third for the patch panels.

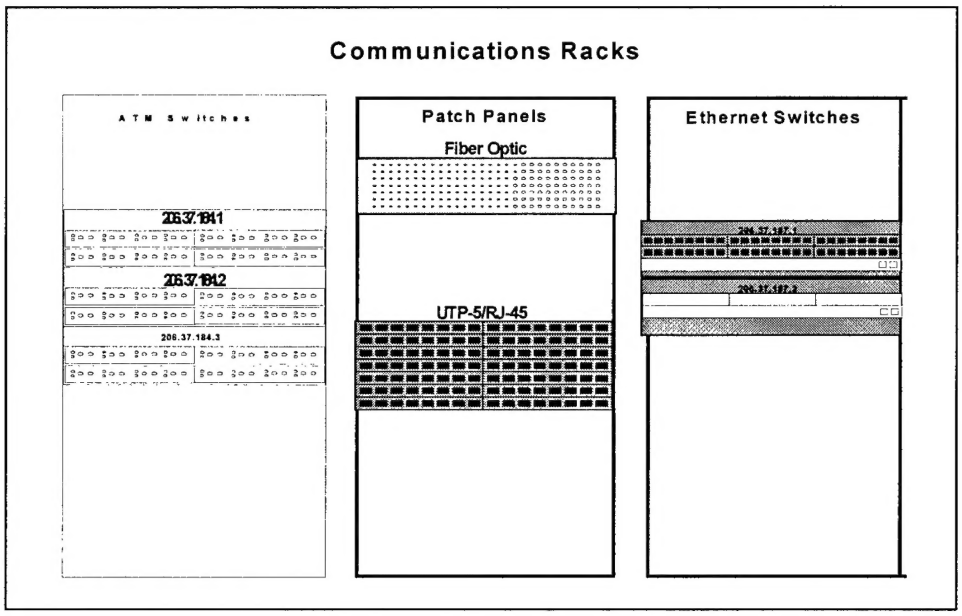

Figure 3. Communications Racks

5.2.1 Patch Panels

There are two types of patch panels. The first type of patch panel contains female connectors of the ST type. At the front of the patch panel Multi-Mode (MM) fiber-optic patch cables are installed from the patch panel to the ATM switches in the ATM communications rack. At the rear, MM fiber-optic cable are installed which are run from the workstation area via the conduit. The second type of patch panel contains female connectors of RJ-45 type on the front. At the front of the patch panel, RJ-45 patch cables are installed from the patch panel to the Ethernet switches in the Ethernet switch communications rack. At the rear Unshielded-Twisted-Pair Category 5 (UTP-5) cable are installed, which are run from the workstation area via the conduit.

5.2.2 ATM Switch Communications Rack

The ATM switch communications rack contains three Fore ASX-200BX ATM switches. Two of the switches contain four 4 port OC-3 switch network modules and a third switch contains two. This provides for forty OC-3 ports total. Patch cables for the ATM switches are MM fiber-optic with ST male connectors on each end. Patch cables connecting workstations operating in the unclassified mode use standard orange MM fiber-optic patch cables. Patch cables connecting workstations operating in classified mode are patched with red MM fiber-optic patch cables.

5.2.3 Ethernet Switch Communications Rack

The Ethernet switch communications rack contains two Fore ES-3810 Ethernet switches. Each switch contains a Network Management Module (NMM), 24 port switch interface card, and a two port 100 Mbit uplink module. One of the Ethernet switches contains an additional 24 port switch interface card. Therefore, the two switches have a total capacity of seventy two ports. The two switches are connected by patching the two port 100 Mbit uplink modules. Patch cables connecting workstations operating in the unclassified mode use blue RJ-45 patch cables. Patch cables connecting workstations operating in the classified mode patched use red RJ-45 patch cables.

5.3 IP Addressing and Routing

The JVL LAN is in fact two LANs. One ATM and one switched Ethernet. Each LAN uses a class C IP subnet. The ATM subnet is 206.37.184.XXX and the Ethernet is 206.37.187.XXX (where XXX is the host address.) All networking devices (e.g. switches, routers, and hubs) use the host addresses 10 and below (except 0 which is reserved). Therefore, all workstations have two addresses: a 206.37.184.XXX address for the ATM interface and a 206.37.187.XXX address for the Ethernet interface.

The ATM switches are named: JVEL1-ATM (206.37.184.1), JVEL2-ATM (206.37.184.2), and JVEL3-ATM (206.37.184.3). The two Ethernet switches are named JVEL1-ETH (206.37.187.1) and JVEL2-ETH (206.37.187.2).

Routing between the two LANs is accomplished by the Video Tele-conferencing (VTC) workstation, which is named JVEL-VTC. Data passes to/from the ATM interface (206.37.184.10) to/from the Ethernet interface (206.37.187.10). The workstation acts as a router between the two interfaces if the IP_Forwarding is turned on during workstation bootup.

5.4 Network Management

Network Management is performed by the Network Management Station (NMS) located in the communications room. Fore systems network management application ForeView is the management interface. The NMS is used for configuration of the ATM and Ethernet switches. The NMS also provides traffic analysis tools such as graphs and reports showing traffic between workstations, traffic between switches, cell loss and bandwidth management.

6. Conclusion

The JVL now has an operational workstation tool and communications environment which allows the JVL operators to use their standard tactical and simulation architectures and activate the JPSD tools to enhance their capability to support the TRAC JVL mission. The facility is operational.